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**NASA TECHNICAL  
MEMORANDUM**

**NASA TM X-73645**

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(NASA-TM-X-73645) A REAL TIME, LOW COST,  
DATA ACQUISITION TELECOMMUNICATION NETWORK  
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**A REAL TIME, LOW COST, DATA ACQUISITION  
TELECOMMUNICATION NETWORK**

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16. Abstract <p>The real-time, low-cost data acquisition communication network described features the use of asynchronous ASCII code transmissions operating at 30 characters per second on the dial-up telephone system. The network features an elaborate, but easily generated error checking system, operating in a line-by-line demand-response mode. The system is readily adaptable for any low speed computer-to-computer data transmissions requiring high reliability in data transmission. The network was developed for the acquisition of pre-launch wind data from the Eastern Test Range at Cape Kennedy to be used by NASA Lewis Research Center, General Dynamics, San Diego, and Martin-Marietta, Denver, Colorado.</p>			
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## Summary

The real-time low-cost, data acquisition communication network herein described was developed to replace an outdated punch card transceiver system. The network features the use of the standard ASCII code, operates at 30 characters per second asynchronously, and has elaborate error checking. The system was designed to be device independent, using demand-response protocol and low-cost dial-up data sets. The network operates synchronously in a real-time mode from the Eastern Test Range at Cape Kennedy, and is used to transmit pre-launch wind data values for the remote calculation of steering-coefficients for the on-board flight computer of a launch vehicle.

The system has proved highly successful in the areas of reliability, performance, and overall time saved in the acquisition and transmission of data by a factor of 5 to 1.

## I. Introduction

On August 20, 1975, a Titan Centaur Launch Vehicle, bearing the Viking I space craft bound for the planet Mars, was successfully launched at Kennedy Space Center. With this launch and all subsequent launches managed by the NASA Lewis Research Center (LeRC) a new data communication network was introduced and used to transmit pre-launch wind data values to LeRC and the NASA contractors associated with the launch. These raw data values are received by the parties in the network and are fed into computers where calculations and wind profiles, pitch and yaw, are made. The prime contractor transmits this calculated data back to the on-board flight computer of the launch vehicle, in the form of steering coefficients. The flight computer then steers the launch vehicle during the critical lift-off phase, thru the winds measured.

The original pre-launch wind data data is obtained from two types of weather balloons, released a given time interval before and up to a launch. Wind velocities and directions are recorded at 200 foot intervals from ground level to 60,000 feet. This data is formatted and punched cards made for the two transceivers. Prior to the use of this system, the pre-launch wind data was transmitted by cards from the Eastern Test Range (ETR) thru an assortment of IBM 066 and 1050 card transceivers, with not all modes of the network being compatible with each other. (See Fig. 1a). The card data was received on like transceivers and hand carried to batch computers at the various sites. Also, in LeRC's case the data cards had to be hand carried from one building to another by courier at ETR requiring a minimum 10 minute delay. These transceivers were subject to frequent mechanical breakdowns and many card re-transmissions. Between the incompatibility of different machines at the different sites and the frequent failures, the need for a new system was clear and evident.

## II. Description of the Network

The foremost consideration in the design of the network was commonality. Each site had different types of large scale computers (See Fig. 1a), made by different manufacturers. The machine codes were incompatible, as were the different methods, if any, of real time data input.

The first requirement then was to establish a standard code for all machines. The American Standard Code for Information Interchange (ASCII 3.4) was selected, and was easily adaptable to most sites.

The second requirement was to upgrade old computer equipment at ETR, the data source, to on-line operation. After extensive contacts with the Control Data Corporation, data controllers and line adapters were found that would fit their system. Also, a switching unit was ordered such that the same data phone input lines could be switched from prime, to back-up computers for both types of data. This proved to be a very advantageous feature, in that not only was redundancy provided, but only 3 modems and phone lines were required for the four computers. (See Figure 1b).

In the case of the receivers interfacing to the network, (NASA Lewis, General Dynamics, and Martin Marietta), each was handled independently. The most straight forward and inexpensive path for on-line interfacing where large machines are involved, is to provide a small buffer computer to handle the data in the demand-response mode, to do the error checking, and to overcome large computer systems incompatibilities without major changes of software. Following this path then, the General Dynamics Corporation elected to use an Interdata 716 which they already had on site. NASA, Lewis developed a system using an Intel 8008 micro-computer and Control Logic hardware (See Fig. 10). Martin Marietta had a Modcomp front-end computer on order, but not yet operational. In the interim, they elected to use their CDC 6671 control unit, modify their supporting software and operate on the network as a conversational terminal.

In the area of actual telecommunications, the Western Electric 103A2 type modem, or equivalent, was selected as the data set to be used. Its maximum limit of 300 baud (30 characters/sec) was well in keeping with the volume of data being transmitted. The average message block requires 2.3 minutes for transmission. The 103A2 type modem is a standard of the telecommunication industry for low speed communication and was readily accepted. It operates in the full duplex mode, thereby requiring no turn-around time or control for acknowledgements.

### III. Data Block Format and System Specifications

#### Data Block Format

In order to minimize the major computer programming conversion efforts, the system was specified such that the data blocks would continue to retain the older systems card images, (see Fig. 2). The 80 character column card also translated nicely into 80 character line TTY compatible computer terminals, used for debugging and actual data monitoring. The data is transmitted in a standard format with line count and type of data (i.e. windsound, jimsphere, or pitch/yaw) listed in the first line. Further identification is given in the second line such as release date, time and data description. (See Fig. 3, 4, 5 for data samples)

Data values follow in the third and subsequent lines until completed. The last line contains the characters EOT followed by spaces, a bell code in column 72, checksum values as in every line, a line feed (LF), and a carriage return (CR). This is followed by the last character transmitted which is a EOT code. The line count line includes all following lines thru the EOT line. It does not include itself (i.e. the first line) in the listed count.

#### System Specifications

##### Physical Requirements:

1. The data will be transmitted in the standard 7 level ASCII character code, with the eighth level being designated as even parity.

2. The transmission rate will be 300 bits per second, 10 bits per character, (1 start, 7 data (Least Significant Bit First), 1 even parity, and 1 stop). (Initially the Control Data Corporation teleprocessing hardware required 2 stop bits for an 11 bit character).

3. The data sets used for transmission will be standard Western Electric 103A2's or fully equivalent, operating in a full-duplex mode.

4. The "line length" of headers, data and "EOT" lines will be exactly 80 characters. Space codes will be used to fill up any blank areas in the header or "EOT" lines. Zeros will fill up any blank positions in data lines. Data, spaces or header information will occupy line positions 1 thru 72, position 73 will be Martin Marietta's special checksum (ASCII printable characters numbered 32 thru 95) and repeated in column 74, and positions 75 thru 80 will be the exclusive OR checksum (ASCII numbers 0-7), each digit repeated once in sequence. A line feed (LF) and carriage return (CR) will always follow the 80th character position.

5. A minimum pause of 200 milli-seconds will follow each transmission of a carriage return to allow for terminal printing mechanism to return to its starting position. When the data has been received and error checked, acknowledgements will be sent by the recipient of the data. A printable exclamation point "!" will be a positive acknowledgement signifying the line is error free and the next line can be transmitted. A printable question mark "?" will be a negative acknowledgement signifying the line is in error and must be re-transmitted. In the event there are six negative acknowledgements (NAK's) for any one line, the data link will be disconnected at the data source and a new line redialed.

6. In the event no acknowledgements are received after a period of 6 seconds, a positive acknowledgement will be



--	--	--	--	--	--	--

assumed, and the next line transmitted (implicit ACK). The purpose of this specification is twofold, the first being to allow the data source computers at ETR to complete the sequence without being tied up indefinitely waiting for a response and secondly, to allow the receivers a fixed time frame for a message transmission. A side benefit also allows the data to be received at a receivers' monitor terminal for visual confirmation without a response being necessary.

#### Operational Characteristics:

1. The Eastern Test Range (ETR) has 3 "ports" or data paths available on different direct distance dialed phone numbers. Those ports may be group switched between the various computers, but all must be switched at the same time depending on the source of data.
2. ETR transmits the data simultaneously thru the three ports upon verbal confirmation that all parties are ready and data is available.
3. The data sequence starts when the receivers each dial-in and transmit a positive acknowledgement (!) to ETR.
4. In the event of errors being detected by one or more parties in the network, the lines in error are re-transmitted. The other parties continue to receive data without delay or interruption.
5. ETR operates only as a data source.
6. Data calls should be terminated (lines disabled) by ETR when the EOT code is transmitted or when 6 consecutive negative acknowledgements have been received for any one line.
7. The General Dynamics Corporation (GDC) operates as both receiver of data from ETR and a transmitter of P/Y values to Martin-Marietta and NASA LeRC.
8. GDC in transmit mode operates in a similar manner as ETR and has two ports available on different DDD numbers.

#### IV. Description of Error Checking

The error checking procedures of a given block of data are many and straight forward, which lead to a highly reliable system of raw data transmission. Current estimated values show typical error rates for the data speed and grade telephone lines used, to be in order of one bit error in 500,000 bits. With the addition of the different forms of error checking applied to the data, it is estimated the probability of an undetected bit error entering the data is as high as 1 bit error in  $10^9$  bits transmitted. The types of error checking done are as follows:

1. Vertical even parity checking on each ASCII character received. (Seven data bits with one parity bit).
2. An exact line length of 80 characters.
3. An exact line count as listed in the first start of message line.
4. Redundancy in line count, and all check sum values (each value given twice).
5. An exclusive OR checksum of a total line.
6. A special checksum summing data bit values and converting them to a printable ASCII character.

An error detected automatically by the receiver, with any one or more of the six error checking methods above would result in negative acknowledgement of the line of data received and cause the same line to be retransmitted. In the event of a difference of line count transmitted and lines received, the EOT line would receive 6 negative acknowledgements and the call terminated for re-dial. Generally any errors received fall into the category of "burst noise" on the telephone circuits. This "burst noise" usually lasts from one to three character times and will be detected by the vertical parity check and both checksums. If the telephone line is continually noisy, the only solution is to be disconnected and re-dial.

### The Exclusive OR Checksum Characters

A checksum will be generated by the data source for each line of data using exclusive OR, binary arithmetic (7 data-bit levels only), without carries. This sum will be converted to ASCII printable characters (0-7) binary to octal conversion and transmitted at the end of the line of data (cc75-80). Each character will be printed twice with the most significant number first. (Reference Fig. 7)

Acknowledgements will be based on the receiver of the data doing similar arithmetic in the Front End computer and comparing it with the transmitted values.

### Martin Marietta Special Checksum Characters

In the development of the network, it was found that the Martin-Marietta CDC 6500 computer had no way using the normal checksum method outlined above, in that the ASCII character values when taken directly in the machine were converted to internal codes and lost their identity for checksumming. This left Martin-Martin without any line checksum features. To overcome this, a special checksum method was derived and placed in Columns 73 and repeated in column 74. The basic operation of this checksum lies in the creation of an internal table within the CDC 6500 such that an integer value will be assigned to each internal code value as it is converted from its ASCII character. This integer value is pre-defined within the 64 ASCII character set. The internal codes are summed in modulo 64 arithmetic as they are received. Then the special checksum character is received it is likewise converted and compared with the sum. If they agree, a positive acknowledgement is sent back. If they disagree, a negative acknowledgement is sent back and the line is retransmitted. A sample of this special checksum is shown in Fig. 8.

## V. Concluding Remarks

Since the network was designed and implemented for the August 20, 1975 Viking A Launch, it has been used successfully in 5 other launches i.e., 1) Viking B, second spacecraft to the planet Mars, 2) AC 36, an Intelsat-IVA Telecommunication satellite, 3) T-C Helios, a West German spacecraft for exploration of the Sun, 4) CTS satellite launched by McDonald-Douglas, 5) AC37 Intelsat IVA, a second telecommunication satellite.

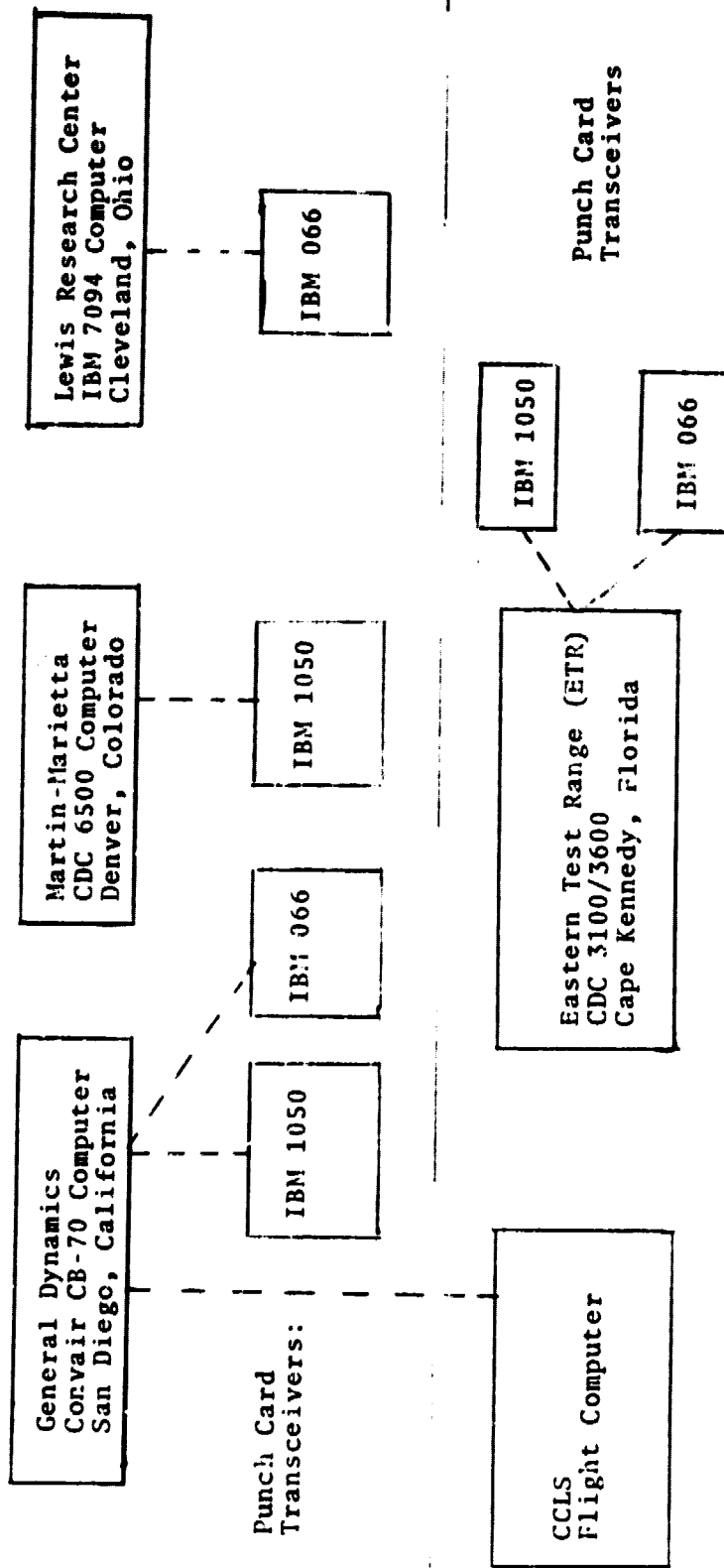
A Windsound plot of the raw data values and a superimposed smoothed curve has been included (Fig. 9) to show typical sample of the data values received.

The on-line experience of the network gained from acquisition of wind data for these launches, revealed the maximum worst case error failures to be the rejection of two consecutive lines, which occurred once during the twenty-four data runs (approximately 72,000 characters). The normal mode generally had no errors. It was found that if the data phone-lines were established for a long period of time prior to data transmission, the first data line occasionally would require re-transmission due to burst noise during the wait period. At no-time has a party in the network been disconnected because of the 6 consecutive error line specification.

An additional benefit comes from the design of the network that allows any receiver can also act as a relay point and re-transmit the data to another party. A single point failure has been eliminated once the data is obtained by one or more parties originally. This feature has instilled a level of confidence in the contractors and NASA Lewis such that all parties have since released their card transceiver equipment which had been kept as an emergency back up system.

In conclusion, it has been shown that the many benefits of the system, in terms of reliability, performance, and time saved in the acquisition of the data, have far exceeded the initial design goals and has already justified the time and expense in the networks development.

The author wishes to acknowledge the contributions of Mr. Fredrick N. Goldberg and Mr. John Estes of NASA LeRC, Mr. Donald Terry of General Dynamics Corporation, San Diego, California, Mr. Robert Hanley of Martin-Marietta Corporation, Denver Colorado, and Mr. Bruce Flickenger of RCA, ETR Florida during the development, debug, and implementation phases of the network.



PRINCIPLE SITES OF THE DATA COMMUNICATION NETWORK  
(OLD SYSTEM)

FIGURE 1a

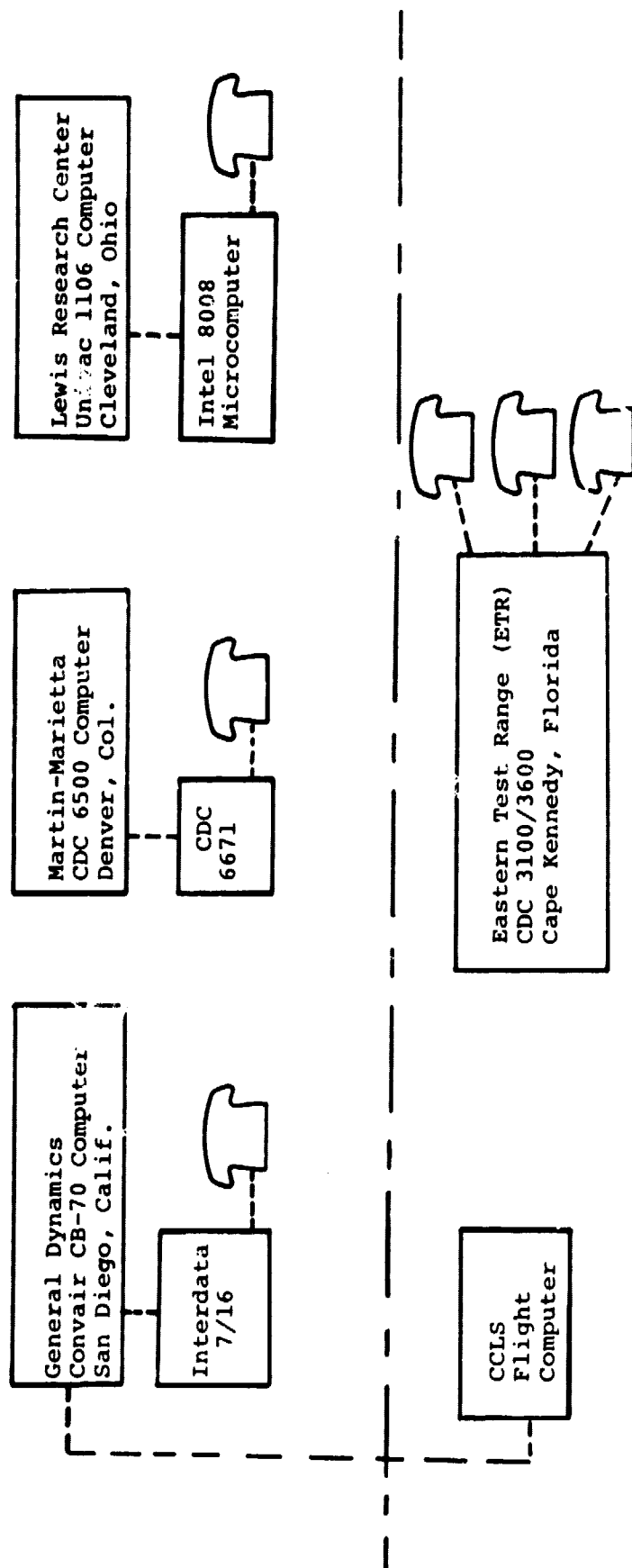


FIGURE 1b

NEW REAL TIME DATA COMMUNICATIONS NETWORK

# Description of Wind Data Formats

All ADDJUST wind and steering data will be communicated with two header lines.

Line No. 1 (for all types of data) will have the character "C" in column 1, the characters "SOM" (start of message) in column 2-4, and two digits in columns 5 and 6 to specify the total number of lines of data in the transmission. The digits specifying number of lines in the message will be repeated in columns 8 and 9. Columns 73 and 74 will carry the special MMC checksum for that line, Columns 75 to 80 will carry the general error checking information for that line. All other columns will be blank. Example:

CSOM 40 40 ID ID MMGGGGGG

(ID identifies type of data i.e. P/Y, Windsound, or Jimsphere)  
 Line No. 2 will have the character "C" in column 1. Columns 3 and 4 will define the type of data (W=Windsonde, J=Jimsphere, R=Rawinsonde, TP=temperature and pressure, PY=steering data). Columns 2, 5, and 6 will be blank. Columns 7-22 will specify the release time of the balloon which defines the data as follows: ,HHmm DD MM YY,. (HH = hours, mm = minutes, DD = date, MM = month, YY = year). Columns 23-72 will define the data as shown in the examples. Columns 73-80 will contain error checking character for line no. 2 as defined above for line no. 1. Examples:

C P Y	,13 04Z	11 08 75,GDC Steering No. 03	PLA0300*TC04	YLA0300*TC04	MMGGGGGG
C W	,13 04Z	11 08 75,ETR Wind data	1234,	ALT 200 F, VEL FPS	MMGGGGGG
C J	,13 14Z	11 08 75,ETR Wind data	1235,	ALT 200 F, VEL FPS	MMGGGGGG
C R	,14 49Z	11 08 75, ETR Wind data	1236,	ALT 200 F, VEL FPS	MMGGGGGG
C T P	,14 49Z	11 08 75, ETR ATMOS data,	ALT 1000 F, PRESS MBAR,TEMP DEG Cx10		MMGGGGGG
EOT		(Last line termination)			MMGGGGGG

(Bell Code)

(EOT Code)

Figure 3 Windsound (W) Sample



38	J	J	0547Z	JS	01	76	ETR	WIND	DATA	2675	ALT	200	F	VEL	FPS	<<002222	//000077
A	001		330	349	353	355	357	000	003	013	015	029	025	036	036	038	052
A	017		334	357	300	308	260	255	241	253	259	278	235	241	260	257	265
A	033		268	276	279	283	279	273	272	271	260	265	267	270	276	279	282
A	049		280	274	270	265	268	269	268	270	274	272	272	273	271	271	271
A	065		272	273	273	270	268	265	260	255	255	252	253	256	255	255	257
A	081		261	262	264	263	260	263	262	263	265	269	267	267	263	264	265
A	097		265	266	264	262	261	259	258	258	258	257	255	253	253	255	255
A	113		256	258	257	257	258	260	261	258	261	262	260	260	257	258	255
A	129		255	255	259	259	257	260	259	260	260	260	258	257	256	254	254
A	145		254	255	257	258	259	259	259	260	261	261	262	261	262	263	264
A	161		267	268	266	266	265	268	266	266	266	267	266	267	268	265	266
A	177		265	265	264	264	266	266	268	268	268	271	270	269	269	265	266
A	193		262	260	259	258	257	258	259	259	261	261	261	259	259	260	265
A	209		257	260	262	261	261	261	259	257	258	259	262	265	266	264	262
A	225		263	263	268	267	269	267	266	264	260	258	256	257	258	259	261
A	241		258	260	264	263	260	256	254	251	251	252	251	252	254	252	253
A	257		253	256	255	257	257	260	263	267	265	268	268	265	261	259	256
A	273		249	251	254	258	259	260	263	266	269	273	274	271	267	264	263
S	001		006	016	027	038	037	040	034	035	031	031	028	029	023	025	018
S	017		007	005	006	007	004	007	008	012	009	011	014	014	017	015	018
S	033		018	022	022	020	019	023	020	020	022	025	025	029	034	039	041
S	049		042	043	042	043	046	045	044	047	047	045	045	046	046	049	050
S	065		050	044	044	047	050	049	048	052	053	053	056	052	053	051	048
S	081		052	055	056	055	056	055	057	061	066	068	071	071	075	079	081
S	097		085	087	087	088	088	088	088	088	087	086	086	085	087	088	090
S	113		087	086	085	086	086	087	090	092	093	093	092	092	094	094	092
S	129		096	097	098	102	099	099	105	105	107	115	111	112	112	112	113
S	145		113	115	116	115	115	115	114	112	113</						

**Figure 4 Jimsphere (J) Sample**

C PY	14	PY	PY	76,GDC STEERING NO. 05	P1A0500*AC38	Y1A0500*AC38**115544	..002222
P2=	0529Z	15	01	76,GDC STEERING NO. 05	P1A0500*AC38	Y1A0500*AC38**115544	..002222
	608789-14,	357632-16,	755672-16,	694324-16,	670009-16,	-375552-16,	77117777
	-303199-15,	101966-15,	207843-15,	592514-16,	134336-16,		00000044
P1=	-788499-10,	-190465-10,	-136517-10,	-118425-10,	-945250-11,	-879390-11,	Y1117777
	-710853-11,	-107889-10,	-104503-10,	-685972-11,	-359565-11,		22000066
P0=	157080-05,	131628-05,	116619-05,	106182-05,	993261-06,	947674-06,	JJ116644
	902766-06,	859643-06,	808248-06,	724529-06,	611035-06,		GG001177
Y2=	147650-14,	423503-15,	-827787-16,	211275-15,	-450200-15,	531094-15,	~117700
	-625774-15,	384839-15,	-496969-16,	-152572-17,	145919-18,		HH000066
Y1=	-126442-10,	-226265-11,	363086-11,	-626241-12,	113502-11,	-206174-11,	UV117700
	418728-11,	-240033-11,	-730755-12,	-301636-12,	-280238-13,		NN000044
Y0=	0,	-176778-07,	-867474-08,	150743-07,	189228-07,	133429-07,	1115533
	163115-07,	216036-07,	192229-07,	694566-08,	302655-09,		88001144
EOT							113311

Figure 5 Pitch/Yaw (P/Y) Sample

Figure 6a - Data Transmission Sequence

Data Call Originator (Data Receiver)  
(LeRC, GDC, MM)

Data Source  
(ETR, GDC)

1. The 103AZ Data Sets are enabled (terminal ready high) by the CPU and are placed in the auto-answer mode.
2. The System Operator initiates data call to source.
  - 2a. Data set answers automatically and places 2020 hz tone on the line.
3. The System Operator places own dataset in data mode by pushing "data button".
  - 3a. Data set receives carrier tone 1020 hz and provides connect status to CPU.
4. The System Operator initiates the data transfer sequence by sending a "!" code (41/octal) (A positive acknowledgement).
  - 4a. The CPU accepts the acknowledgement code and transmits the first line of data.
5. The system receives the line of data and analyzes the error codes transmitted at the end of the line.

If there are no errors the system automatically transmits a positive acknowledgement "!".

If there is an error, a negative acknowledgement "?" is automatically transmitted.

  - 5a. The CPU analyzes the acknowledgement code received and does the following:
    - A. If it is a positive acknowledgement, the CPU will transmit the next line of data.
    - B. If it is a negative acknowledgement, the CPU will transmit the same line of data over again.

Figure 6a - Concluded

6. This process (step 5 and 5a) is repeated until the whole data block is transmitted. If there are six negative acknowledgements for any one line, the sequence is stopped and the line disconnected.
7. Following the last line of data, the characters EOT and a EOT code is transmitted. (04 octal)
8. The EOT code is received and detected, indicating the transmission is complete. The data set is disconnected (terminal ready dropped) automatically.
- 8a. The CPU senses the loss of carrier and drops terminal ready disconnecting the data set and phone line.

Figure 7 - Sample Calculation of Checksum

First Line	ASCII Character/CODE/8	Binary Value
1st character	C	1 0 3
2	S	1 2 3
3	O	1 1 7
4	M	1 1 5
5	4	0 6 4
6	2	0 6 2
7	Space	0 4 0
8	Space	0 4 0
9	4	0 6 4
10	2	0 6 2
11	Space	0 4 0
12	Space	0 4 0
13	W	1 2 7
14	Space	0 4 0
15	Space	0 4 0
16	Space	0 4 0
17	W	1 2 7
18-72 <sup>2</sup>	Space	0 4 0
73	L	1 1 4
74	L	1 1 4
75	X <sub>1</sub> = 0	
76	X <sub>2</sub> = 0	
77	Y <sub>1</sub> = 2	
78	Y <sub>2</sub> = 2	
79	Z <sub>1</sub> = 2	
80	Z <sub>2</sub> = 2	

1 - where  $X_n$ ,  $Y_n$ , and  $Z_n$  are generated checksum values and converted to ASCII printable characters (i.e.  $X + 60/8 = 6X/8$ )

2 - Note: In exclusive OR summing without carries, even repeated characters are self canceling.

Figure 8 - Sample Calculation of Martin-Marietta's  
Special Checksum

I. Sample Integer Assignments

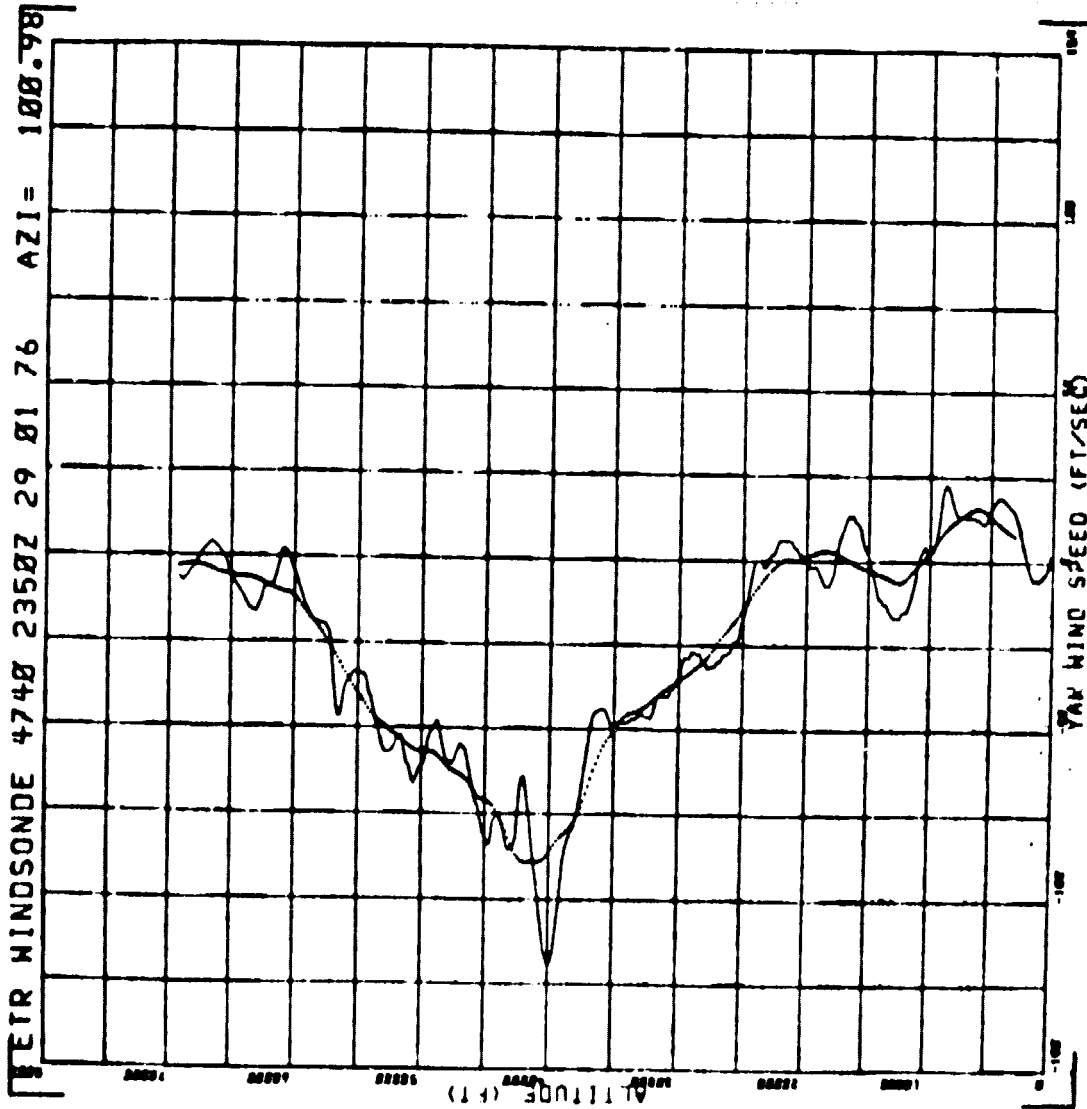
<u>ASCII Character</u>	<u>Octal Value</u>	<u>Sequenced Integer Code</u>
Space Code	0 1 0 0 0 0 0	0
0 (Zero)	0 1 1 0 0 0 0	16
C	1 0 0 0 0 1 1	35
P	1 0 1 0 0 0 0	48

II. Checksum Calculation for First Lines

	<u>ASCII Character</u>	<u>Integer Value</u>
1st Character	C	35
2	S	51
3	O	47
4	M	45
5	4	20
6	2	18
7	Space	0
8	Space	0
9	4	20
10	2	18
11	Space	0
12	Space	0
13	W	55
14	Space	0
15	Space	0
16	Space	0
17	W	55
18-72	Spaces	0
		<u>364/10</u> = 554/8

5 54/8 = 44/10 decimal integer value

The ASCII character for integer value 44 is "L", which is then transmitted in columns 73 and 74.



Sample Plot of Wind Data

Figure 9

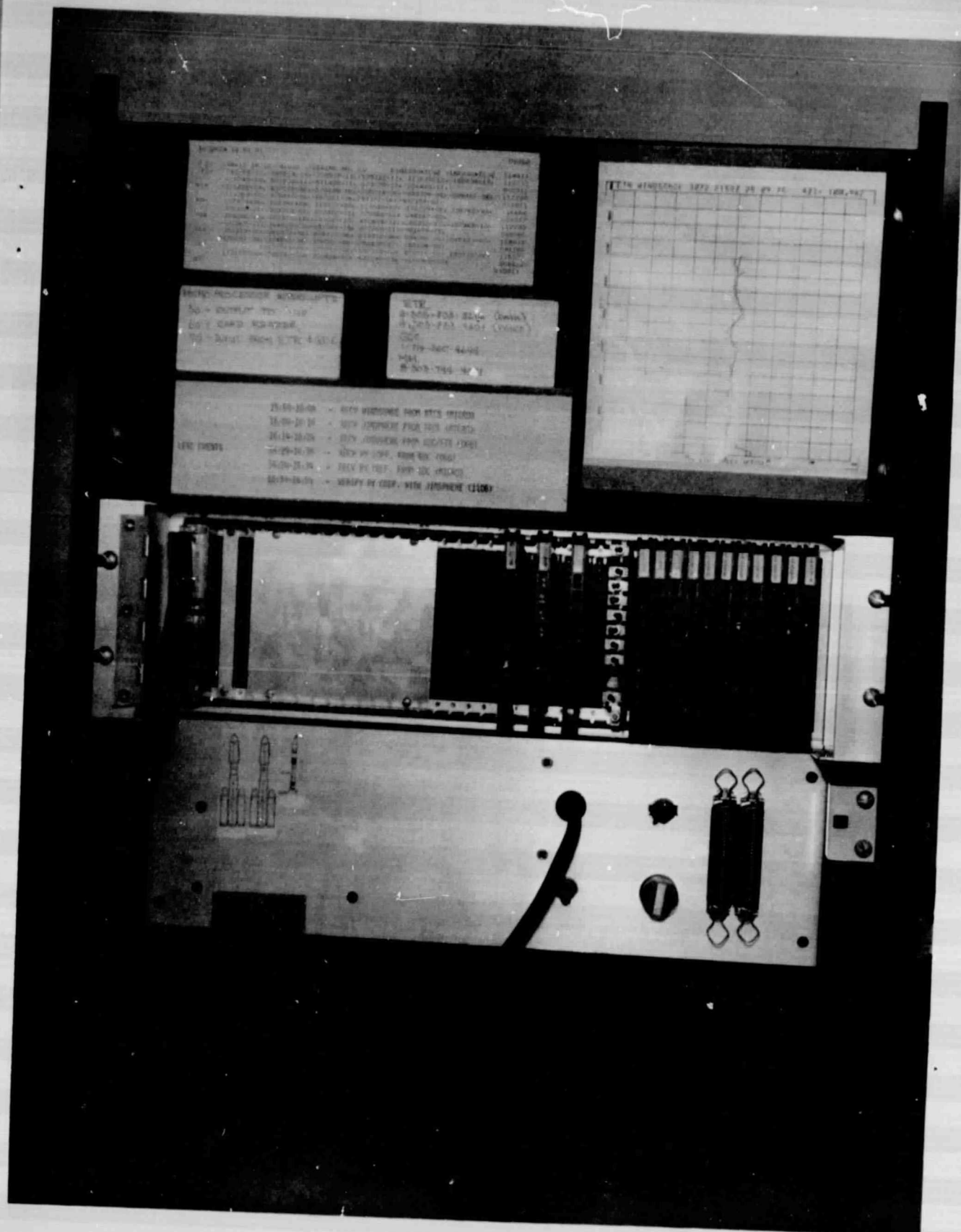


Figure 10 - Micro-Computer

REPRODUCIBILITY OF THE  
ORIGINAL PAGE IS POOR